

Transport and Logistics Performance Assessment: Beyond the Conventional Approach

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Abstract. Assessment of transport projects and policies is traditionally performed by means of conventional approaches, such as the cost-benefit or multicriteria analyses. However, these methods are complex and unable to incorporate the multifaceted perspectives that transport planning and governance require. For this reason, simpler and more tailored methods to evaluate specific transport solutions are being pursued. This paper explores the potential of index-based methods to assess sectorial transport policy and innovations. The focus is put on the environmental, social, and operational performances. The distribution of goods using public transport means, also known as freight-on-transit (FOT), is used as a case study, to be assessed by means of appropriate indexes. Benefits and trade-offs compared to traditional evaluation methods are highlighted. Moreover, generalized guidelines for the definition of appropriate sets of indexes are provided, starting from the application within the FOT framework.

Keywords: Performance Assessment · Freight-on-Transit · Index-Based Method · Transportation Decision-Making

1 Introduction

Transport researchers and practitioners are acquainted with the need to assess the impacts and implication of each transport choice, at all stages of the decision-making process: *ex-ante* (before the choice is made), *in itinere* (while the decision is being implemented), and *ex-post* (when the project/policy is delivered and operational) [1]. In practice, transport projects appraisal is normally based on the cost-benefit analysis (CBA), as required by laws and regulations in most European countries [2, 3]. In few cases, the CBA is integrated or substituted by other appraisal methods. Among them, the most commons belong to the family of multicriteria analyses (MCA). Both CBA and MCA, however, present several issues that can affect the transportation decision making process, making it less effective and transparent. The CBA is based on welfare economics and is often regarded as excessively efficiency-oriented, incapable of capturing social, ethical, equity and fairness issues [4]. Furthermore, several discretional aspects in the monetization process may lead to distorted results. The MCA, instead, is very much discretional and its validity depends on the competences and priorities of the stakeholders involved in

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the decision-making process, from political authorities to technical experts, to citizens. The risk is to propose assessments based on superficial qualitative inputs and limited quantitative support, or to evaluate alternatives based on weights that are not representative of the multi-faceted framework of actors [5]. Hence, traditional appraisal methods are at the same time excessively complicated and only partially effective for smaller-scale transport policy and decision-making. For these reasons, scholars and practitioners explore other possible solutions to evaluate business models and process improvements. These approaches involve simpler processes and have greater focus on desired appraisal components, rather than seeking an overarching -but often incomplete- approach.

In this paper, we debate the use of index-based methods (IM) as an integration to traditional appraisal tool (mainly based on CBA and MCA), for achieving a more comprehensive and effective decision-making process. In this analysis, we consider operational, environmental, and social impacts, by discussing advantages of index-based methods, as well as inevitable trade-offs compared to more complex assessments. We present the evaluation of freight-on-transit (FOT) schemes as a subfield of transport policy where performance evaluation by means of indicators can be consistently adopted.

The remainder of this paper is structured as follows: Sect. 2, starting from existing literature, discusses more in detail the main drawbacks of conventional appraisal in the transport sector; furthermore, it introduces IM as a possible integrative solution to improve the reliability of the assessment. Section 3 describes IM from a conceptual and methodological perspective. Section 4 introduces FOT as a transport policy innovation and explores the use of IM within FOT assessment. Finally, Sect. 5 draws some guiding principles and concludes the paper.

2 Conventional Appraisal Tools and Index-Based Methods

2.1 Conventional Appraisal Tools

The CBA is the most widely adopted appraisal tool within the transport sector in the Western world [2, 3]. Being prescribed by norms and European guidelines, and taking advantage of a standardized process, the CBA gained broad acceptance. Its outcomes are often taken as dominant criteria for decision-making. A large body of literature is available on the CBA, going beyond the scope of this article: for methodological and content details, readers may refer to Mishan and Quah [6]. Synthetically, the CBA measures the desirability of a transport option based on welfare economics [7], following an efficiency criterion that leads to recommending projects in which monetary gains outweigh the sum of monetary losses [8]. This process requires the conversion of each impact into monetary values, using discounted values to acknowledge people's attitude towards present and future consequences [10]. Yet, there is increasing awareness that the CBA cannot provide a comprehensive aid to transportation decision-making, as its efficiency-oriented approach fails to address sustainability, (intergenerational) justice, and fairness issues [4]. According to Vassallo and Bueno [11], the arbitrary assignment of monetary values to "priceless goods", such as most of the social and environmental ones, is a main limitation of the CBA, also considering that these "priceless goods" are at the very base of the concept of sustainability, a priority in contemporary transportation decision-making. Being aware of this, scholars and practitioners have explored other

solutions. In the last decade, the MCA has gained some attention as an alternative or complementary method to the CBA. It consists of a multi-objective decision-making technique useful for *ex-ante* appraisal, particularly suitable to situations in which single criteria (e.g., economic efficiency) do not fully satisfy the scope of the analysis [12]. Within the MCA, the assessment criteria are chosen by the decision-makers. At a later stage, criteria are weighted according to target groups and stakeholders' preferences. The ability to capture multiple perspectives is also regarded as the main drawback of the method, given the excessive discretional power of involved experts. Because of this, the MCA is often mentioned by European institutions as a valid complement to transportation decision-making, but it is not part of official appraisal processes [13].

In short, traditional appraisal methods offer valuable insights into the effectiveness of transport projects and long-term policies, but the efficiency-oriented focus of the CBA and the discretionary aspects of the MCA hinder their capacity of providing comprehensive outcomes. Moreover, the complexity of these methods complicates their use by transport decision-makers and practitioners working for smaller entities and/or dealing with limited data. Indeed, the availability of vast and reliable information to both policymakers and involved stakeholders is fundamental for an effective appraisal process through the CBA and MCA. An additional element of complexity of these methods is the need for extensive and adequate stakeholders' involvement. Ignoring the perspective of some concerned groups can mislead the planning process, leading to suboptimal decisions. Within this context, several alternatives have been proposed and, in few cases, integrated as a support to conventional appraisal tools.

2.2 Beyond the Cost-Benefit Analysis: Towards an Index-Based Assessment

Vassallo and Bueno [11] proposed a method for the intertemporal aggregation of environmental, social, and economic impacts of transport projects, called STAR. STAR weights criteria through Rembrandt pairwise comparison, based on previous real-life application. This overcomes the mono-objective limit of the CBA while obtaining a comparable and quantifiable multi-objective evaluation. Alternatively, the family of Life Cycle Analyses can be adapted to assess social, territorial, or other categories of transport-related impacts. These methods, however, present similar complexities to that of the CBA. A consensus on the impacts to be included has not yet been reached, thus limiting the practicality of the tool [11]. According to the specific subject of evaluation, other tools have also been developed, such as the Wider Economic Impacts assessment [4, 14], Spatial Impacts Analysis, and partial or general equilibrium models [15]. Rather than replacing, they can support conventional appraisal to cover some of the fields that are left unassessed by them, with particular reference to social goals and objectives not pertaining to the concept of efficiency.

To evaluate impacts of transportation choices while reducing the overall procedural complexity, several authors and practitioners have opted for the use of performance indexes (or indicators). These can be supported by spatial analyses by means of Geographic Information Systems (GIS). Indexes can be both qualitative and quantitative, although the latter are more frequent as they allow for more comparable results [16, 17].

The main advantage of IM is that they simplify the assessment to straightforward formulas, clearly expressing the data input and the significance and interpretation of

output values. Like more conventional and overarching assessment methods, index-based evaluation presents some challenges. First, the definition of the appropriate set of metrics for each context is complex. For this reason, it is important that transportation decision makers receive adequate education and that they can rely on extensive guidelines and manuals. Second, IM necessarily compare different scenarios: typically, they assess the difference between an *ex-ante* situation, where the transport project or policy is not in place, and one or more *ex-post* conditions, that must be adequately described and simulated. However, the completeness of the assessment can be enhanced by providing a scenario analysis, with several varying conditions [18].

Overall, IM can improve the efficacy and reliability of transportation decision-making by simplifying several steps of the process, from data acquisition and elaboration to the overview of different scenarios and varying conditions. The assessment through IM, then, is more manageable by means of professionals that are less expert in assessment techniques, but still are faced with the need to make the right decisions. Still, IM have some drawbacks: unlike more comprehensive analyses, they generally do not include a public engagement phase; their main advantage of being focused on selected aspects can also be a limit; and, mostly, they are only effective if they are carefully chosen and thoroughly calculated.

3 Performance Indexes in Transportation Decision-Making

Indicators have been used in the field of transport since the 1992 United Nations Conference on Environment and Development. Their adoption is traditionally linked to the study of sustainability within the transport sector [19]. Indexes are defined as "selected, targeted, and compressed variables that reflect public concerns and are of use to [transportation] decision makers" [20]. Whereas consensus on a universal methodology for the assessment of transport performances through IM has not yet been reached, several criteria that indicators must follow have been stated [21]. They include consistency with assessment goals, conciseness and appropriateness (based on needed detail), availability, measurability, robustness, comprehensibility, sensitivity and reciprocity. Sinha and Labi [1] say that performance metrics for transportation decision making must satisfy five properties:

- Suitability: the indicator should be influent and appropriate for the purpose at-stake;
- Measurableness: the indicator must be easily and objectively measurable. Results, moreover, must satisfy certain standards of reliability and accuracy;
- Realism: collecting, generating and extracting relevant data relating to the indicator should be possible without investing excessive resources;
- Defensibility: the indicator must be defined and developed in a clear and concise manner. Moreover, its assessment and interpretation should be clearly communicable to decision makers and public;
- Universality: IM should be generalizable and applicable to individual or combined modes. In this sense, the use of dimensionless quantities is a valid opportunity.

Performance measures are fundamental in assessing transportation decisions in relation to community objectives and resource allocation. More in detail, IM are particularly

suitable for comparing trends and impacts across communities and territories, for understanding impacts of different decisions, and to evaluate progress towards or away from defined transport or society goals and targets [22]. Meyer [23] classifies indexes in general performance metrics (including population, mobility indicators, vehicle kilometers and hours), effectiveness measures (availability, quality, and supply of transport services), and efficiency measures (cost efficiency, occupancy ratio and vehicle utilization, productivity, energy use, financial sustainability). A different three-tier classification, based on service quality, outcomes, and cost efficiency, is proposed by several authors, including Carter and Lomax [24], Litman [25], and Vuchic [26].

Recently, IM have been adopted for the assessment of several impacts within the wider context of transportation decision-making. Relevant applications are those regarding urban resilience [27], accessibility [28, 29], sustainability performance [30, 31], safety [32], and energy use [33]. Notably, IM have been recently used to approach the assessment of innovative processes in urban logistics and first-last mile transportation of passengers and goods, which are among the most challenging aspects of contemporary transport operations and planning [22].

4 A Case Application of Index-Based Assessment

4.1 Freight-on-Transit

FOT (i.e., the integration of passengers and cargo flows on the same vehicles (typically, buses) is among the innovative solutions that are studied to reduce the significant impacts of the passenger-freight first-last mile [34, 35]. The discussion of first-last mile issues is not in the scope of this paper: interested readers can refer to Arvidsson et al. [36] and Cavallaro and Nocera [37] for a broad overview. FOT aims at increasing efficiency and efficacy (or reliability) of passenger and freight transport, resulting in more financially viable operations in both dense urban cores and rural, low demand areas [36, 38]. According to FOT studies, this implies lower direct and generated costs for all involved stakeholders, more care for environmental issues, and higher social value [22]. The concept mainly represents a conceptual, normative, and procedural innovation. Some physical modifications to the mobility system are needed (such as operating consolidation hubs and adapting transit fleets and stations to goods transport and deposit), but most assets, including the transport infrastructure, the natural and anthropic environments where the system operates, and the vehicles themselves, receive no or minor modifications. Yet, the business models, routing schemes, and priorities of both passenger and freight carriers change significantly. Other stakeholders of the passenger transport and supply chain fields are also impacted, from shopkeepers to planning agencies [39].

Assessing the effects of such an impactful transport measure, requiring limited initial investment and minimal structural modifications, is challenging. Traditional appraisal is not suitable for the objective, being unable to capture the benefits and drawbacks of locally developed transport policies [9]. This is exacerbated by the fact that FOT contributes to the social and environmental goals of the transport sector through operational innovation rather than through technological development or investment in sustainable infrastructure. The operational aspect of the FOT has indeed received a fair amount of attention from researchers. Several studies have developed or adapted routing problems

to correctly model FOT in both urban and rural settings [40–43]. In most cases, scholars developed variants of metaheuristic approaches to routing and pickup-delivery problems with varying constraints. The mathematical solution of these problems, though, does not provide guidance to transportation decision makers to understand under which circumstances it is convenient from the perspective of the main involved stakeholders to switch to FOT rather than performing freight and passenger transport independently. Moreover, effective assessment should determine if FOT provides more frequent and cheaper services at comparable costs for both the funding authorities and customers, and if FOT contributes to increasing the social acceptability of transport and logistics. To address this issue, a few national and EU-funded projects have tested FOT applications in real life [44, 45], developing both a conceptual framework for FOT operations and an evaluation framework. Within this context, IM have been identified as a promising evaluation method, especially for assessing the sustainability, financial viability, and social impacts of the system.

4.2 Index-Based Assessment for Freight-on-Transit

Within transportation decision-making, IM are used to evaluate performances both at the network level (to program, set priority, and estimate funding) and project level (to select the best policy and design). Chosen indexes should respect the overall properties of indicators in order to be effective, as discussed in Sect. 3. Moreover, the set of indicators should be restricted and targeted to FOT and to the specific setting under evaluation, avoiding the risks of redundancy and inconsistency [46]. In accordance with Trentini and Mahlene [35], FOT on buses and other transit vehicles is particularly suitable for indicator-based assessment. Other types of passenger-freight integration, such as cargo trams on shared tracks and infrastructural and nodal sharing more in general, require more specific and technical evaluations. To effectively assess FOT and successfully substitute conventional appraisal methods, providing simpler and more thorough results in support to decision-makers, the selected set of indicators must be able to include the multiple perspectives of involved stakeholders (including transit operators and logistics companies, transit users, clients, residents, and retailers). Additionally, they must provide an organic synthesis of the passenger and freight components, safeguarding their peculiarities while evaluating a unified framework [22, 47].

Literature is not abundant when discussing the use of IM to assess FOT settings. However, scholars have recently taken some steps forward, following a framework based on literature [22, 48–51], also tested and validated within some EU-funded and national projects specific for FOT. Among them, NOVELOG [45] and COCKPIT [52] are notable. The focus is put on four main assessment categories (financial, operational, environmental, and social) [25, 48, 52] within the wider context of transport Efficiency, Effectiveness, and Equity (the "3E" of transport planning) [47]. Table 1 shows the categories of indexes for FOT evaluation proposed by different authors in up-to-date literature and the total number of suggested indicators.

Each of the categories presented in Table 1 can be assessed by means of a limited set of indexes, describing in detail the system's performance compared to the *status quo*. Referring to Bruzzone et al. [47], for instance, financial indicators include the transport cost per unit of passenger or freight and the affordability of the same movement for

Table 1. Indexes for assessing the performance of Freight-on-Transit: categories and set abundance.

Source	Categories of indexes	Suggested no of indexes
Ali et al. [53]	Strategic determinants, Information systems, Infrastructure management systems, City logistics	33
Anderson et al. [54]	Financial, Operational, Environmental	11
Behrends et al. [55]	Actors' involvement, Transport intensity, Traffic intensity, Technical capability	17
Bruzzone et al. [47]	Financial, Operational, Environmental, Social	11
Bruzzone et al. [22]	Operational, Environmental, Social	7
Cavallaro and Nocera [51]	Financial, Operational, Environmental, Social	8
Lindholm and Behrends [56]	Planning principles, Land use, Accessibility, Transport, Traffic	n.a
Litman [25]	Service quality, Outcomes, Cost efficiency	64[b]
Mazzarino and Rubini [49]	Transport supply, Transport availability, Spare capacity	4
Muriel et al. [57]	Livability, Operational	5
NOVELOG [45]	Economy and energy, Environment, Transport and mobility, Society, Policy and measure maturity, Social acceptance, User uptake	137[a]
Pietrzak et al. [58]	Service, Infrastructure, Impact, Quality of Life, Profit	9
Posset et al. [52]	Operational, Service quality, Environmental, Financial	96[a]
Shah et al. [59]	Demand and context, Affordability and accessibility, Mobility, Economic development, Quality of life, Operational efficiency, Environmental and resource conservation, Safety, Infrastructure condition and performance	20
Teychenne et al. [60]	Financial, Social	9
Van Duin et al. [61]	Jobs, Emissions, Safety, Operations	5

[a]Comprehensive lists from which decision-makers are expected to choose according to policy objectives and context characteristics.

[b] Selection made by the authors on more extended set designed for all transport modes.

customers. Operational indicators refer to overall distances, traffic, frequency, fuel and energy consumption, as well as to reliability and punctuality. Environmental indicators deal with the various types of pollution and with the impact on land use and, finally, social indicators include both internal aspects (i.e., the impact on the labor sector) and exogenous aspects (i.e., the stakeholders and public acceptance of transport and logistics operations).

5 Conclusions

In addition to conventional appraisal methods, IM are considered effective tools to assess operational innovation and transport policy. Yet, they aid transportation decision makers thanks to their simplicity but, meanwhile, great capacity to incorporate multiple perspectives and objectives, even in absence of relevant infrastructural or service investments. Simple does not mean trivial. The ability of IM to assess potential impacts of transport policies while reducing the complexity of the assessment process and its discretion is one of the main drivers for the promotion of index-based assessment. However, the definition of the set of indicators, of the timeframe to consider when performing the assessment, and the incorporation of index-based appraisal in consequent decision-making process is still challenging. To address this last issue, it is important to follow a scalable approach, starting with small-scale applications (including real-life tests and pilots, but also incremental application of fully developed policies), and continuously monitoring the coherence of observed impacts with the results of the appraisal process. Monitoring and adaptation, which are essential steps of any decision-making process, remain vital also following decisions aided by index-based appraisal.

When referring to freight on transport, the need for tools assisting transport planners and practitioners in choosing the most suitable indexes has been scarcely addressed. Still, future efforts should be expected by scholars and institutions to provide more comprehensive and standardized guidelines. These are needed to ensure that the index-based assessment is effectively chosen to aid transportation decision-making, substituting or in complement to conventional appraisal, and reducing the risk of unsupported decisions, overcomplexity, or incapacity to capture all relevant components to be assessed. The institutionalization of index-based assessment and its inclusion within transportation decision-making tools and plans (here including Sustainable Urban Mobility Plans), could be a relevant driver for the diffusion and perfection of the methodology.

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